Anomalous EM signals and Changes in Electrical Resistivity at Parkfield: Collaborative Research Between the Universities of California at Berkeley and Riverside and Oregon State University

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Investigations Undertaken:

This project is part of a collaborative observational study of possible electromagnetic (EM) earthquake precursors on the Parkfield segment of the San Andreas Fault. EM data are currently being collected by researchers at UC Berkeley (two magnetotelluric systems, at Parkfield and near Hollister) and UC Riverside (an array of long electric dipoles). The work at Oregon State University supports these efforts, with a focus on development and application of data processing methods for the EM data. Our ultimate goal is removal of ionospheric and cultural EM noise, to improve chances of detecting (and verifying the source of) possible EM signals generated inside the earth by tectonic activity.

Recent effort at OSU has been to develop user friendly computer codes for routine processing of data from the UCB MT sites. The processing system includes automated processing scripts for routine daily multi-site processing of data, as well as a graphical user interface for interactive processing and plotting of raw data, residuals, and various diagnostics of data quality. Results from the routine daily processing (including estimates of MT inpedances, inter-station transfer functions, estimates of noise amplitudes, and summaries of frequency and time domain residual amplitudes) are archived for statistical analysis and correlation with other geophysical data. The routine processing system enables more-or-less automatic monitoring of system functionality, and makes it easier to maintain a high rate of quality data return.

The user interface developed for interactive reprocessing has been developed in MATLAB and includes modules for downloading MT data archived at the BSL, for plotting time series and diagnostics of data quality, and for running frequency domain analysis programs. The interactive software can also be used for time domain filtering and display of residuals. Over the past year the software has been ported to a PC running Windows XP, a manual has been written, and the code has been set up for two individual users at UCB, who are using the code for analysis of data around the time of the recent Parkfield earthquake. The code will soon be made available (along with some initial

training in usage) to users at USGS, Menlo Park, and Stanford University, who are in the early stages of installing additional EM monitoring sites in the SF Bay area under NSF Earthscope funding.

We have also made several significant refinements to the data processing system over the past year to increase robustness of automated processing, and to make the system easier to use for interactive reprocessing and examination of unusual noise events. In addition to the automatic processing of 1 hz data in one day long segments, we have now made it easy to set up and reprocess all data in segments of arbitrary length. Processing of 40 hz data has been added, and inclusion of the UCR dipole data in the multiple station analysis is now possible. We have also added features including automated computation of frequency domain residuals, and tools for quickly plotting summary results as a function of time. Any apparently anomalous noise sources or changes in resistivity can then be investigated using the interactive plotting system. Times of obvious equipment malfunction or other identifiable problems can be marked interactively, and if appropriate, the data reprocessed with the click of a button. A database for keeping track of changes in the system configuration and response has been set up. Through this system we can more easily eliminate obvious system problems, and focus investigation on any remaining noise anomalies that might be correlated with seismic activity. The streamlined processing codes will also make it easier to reprocess all data with any new schemes that might be developed in the future.

Several novel approaches for improved computation of residuals are now under development as part of this system. These include a time domain filtering approach being developed at UCB (soon to be added to our processing package) and a multivariate prediction method that can use all data channels to reduce the effects of local noise on predicted EM fields, and allow for more complex natural and cultural sources. This scheme shows promise for more effectively dealing with cultural noise from the San Francisco Bay area. A second approach in the early stages of development is to use a complex invertable wavelet transform for transformation into the frequency domain. In combination with the frequency domain multiple station processing, this approach should allow for a more reliable isolation of anomalous EM signals.

Results:

As an illustration of this system we have reprocessed data for two years, from mid 2002 to mid 2004. The 1 hz data are processed in 10 day segments. Some representative results are presented in Figures 1-2. We have just completed verifying system response characteristics for older data so that a complete analysis of the backlog of data from the array, including analyses of time and frequency domain residuals, and of MT impedance stability will then be completed.

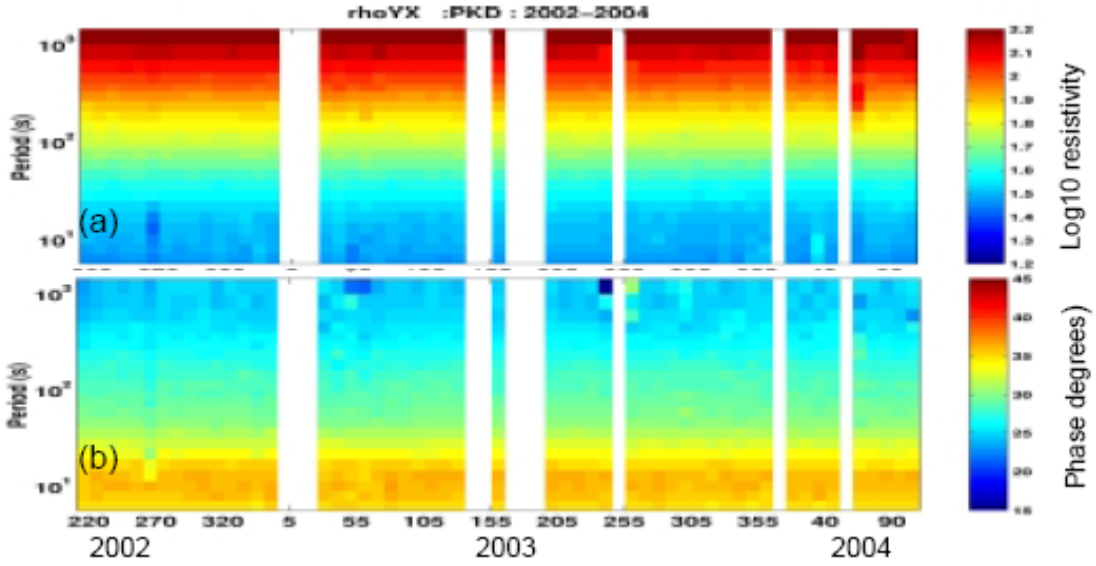

Figure 1. Apparent resistivity (a) and impedance phase (b) estimated in 10 day windows from mid- 2002 to present for Parkfield MT array. Although there are some slightly anomalous results, there is little evidence for temporal change over this period. Careful interactive editing was required to eliminate data from times with persistent system problems, and to verify that system response parameters were correct.

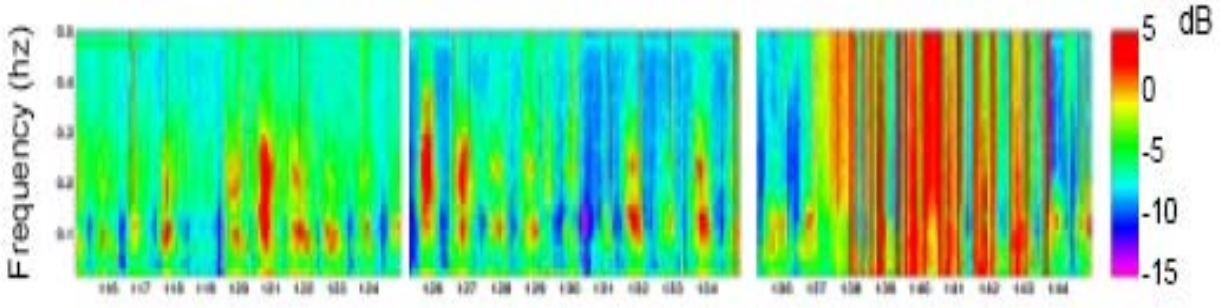

Figure 2. Time/frerquency plots of Parkfield electric field residual amplitudes, normalized to typical electric field amplitudes, in dB. Results for 3 consecutive 10 day segments from mid-2003 are plotted. Note that large residuals almost always tend to occur at particular times of the day and in particular frequency bands. These patterns must be taken into account in assessing significance of possible anomalous noise events. In the third segment (right) electric field noise of a different pattern is seen; checking time series provided clear evidence for electrode failure during this period.

Non-Technical Summary:

This project is part of a search for possible electromagnetic (EM) earthquake precursors on the San Andreas Fault near Parkfield California. There have been a number of reports of anomalous EM signals preceding large earthquakes, and it has been suggested that such signals could be useful predictors of seismic activity. However most observations of EM precursors have been fortuitous, and difficult to verify. This project aims at more systematic monitoring, so that any possible precursors in the Parkfield area would be observed under more controlled circumstances. The work at Oregon State University supports field efforts, with a focus on development and application of data processing methods. Our goal is to remove ionospheric and cultural EM noise, thus improving chances of detecting and better understanding the nature of any EM signals associated with earthquakes.